# IAEA Activities Related to Research Reactor Production of Radioisotopes

DOE Workshop on The Nation's Needs for Isotopes: Present and Future

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# IAEA Activities

## Outline

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- RI Production in Research Reactors (RR)
- RR Produced Radioisotopes
- RR Status
- Design Features for RI Production Reactors
- IAEA RR-Related Activities, Organizations
- CRP on Mo-99 from LEU/Neutron Activation
- Summary
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# IAEA Activities

## IAEA Mandate

- Seek to accelerate and enlarge contribution of nuclear energy to peace, health and prosperity throughout the world – especially to developing countries.

- Relevant programmes, projects, and activities:
  -development, operation, use of research reactors, RR fuel, RI targets
  -RR waste and spent fuel management
  -isotope production technology (reactor products; generators; cyclotron products)
  -radiotracers, sealed sources
  -promulgate and promote nuclear and radiation safety standards, health physics practices, QA/QC, etc.

- ***NOT ADDRESSED in this presentation***:
  -development and use of cyclotrons, accelerators
  -production of very short-lived isotopes (e.g. PET tracers)
  -radiopharmaceuticals development
  -clinical applications of isotopes

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# IAEA Activities

## RI Production in Research Reactors

- Natural or enriched targets inserted into reactor core or reflector region via irradiation rigs
- Medium to high flux reactors ($10^{13}$ -$10^{14}$ neutron $cm^{-2}$ $s^{-1}$; and >$10^{14}$ neutron $cm^{-2}$ $s^{-1}$) provide required neutron source.
- Material is irradiated for various periods of time
- Fission or neutron capture results in isotope of interest (depending on unique physical properties desired)
- Chemical separation and processing in shielded hot cells to separate Mo-99 from fission products.
- Generators (for Mo-99/Tc-99m from fission or neutron activation; tungsten-188/rhenium-188), radioactive decay produces daughter products, combined with various carrier molecules for in vivo use

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# IAEA Activities

## RR Produced Radioisotopes

***Established products in large-scale use***

$^{32/33}P$

$^{35}S$

$^{51}Cr$

$^{82}Br$,

$^{99}Mo$-$^{99m}Tc$,

$^{89}Sr$,

$^{125/131}I$, $^{192}Ir$, $^{60}Co$

*Increasing interest in new products*

$^{90}Y$

$^{75}Se$

$^{153}Sm$

$^{166}Ho$

$^{177}Lu$

$^{186}Re$, $^{188}W$-$^{188}Re$

$^{117m}Sn$

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# IAEA Activities

## RR Produced Radioisotopes

***Low-Flux Reactors:***

$^{24}Na$, $^{32}P$, $^{56}Mn$, $^{64}Cu$, $^{198}Au$

***Medium-Flux Reactors:***

$^{82}Br$, $^{99}Mo$-$^{99m}Tc$, $^{125/131}I$, $^{177}Lu$, $^{166}Ho$, $^{186}Re$,$^{153}Sm$, $^{169}Yb$

***High Flux reactors***

$^{89}Sr$, $^{192}Ir$, $^{60}Co$, $^{75}Se$

***Very High Flux Reactors (HFR, RIAR)***

$^{188}W$-$^{188}Re$, $^{252}Cf$

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# IAEA Activities

## Status of Research Reactors

- Approximately 245 operating RRs worldwide; 173 are more than 30 years old, although refurbishment is common
- Very few new ones opened recently (Australia, Egypt, Germany, Morocco)
- Few RRs under construction (France/EU) or planned (Azerbaijan, China, Jordan, Gulf States, Netherlands)
- MAPLE isotope production reactors recently terminated by AECL Canada

- U.S:

  -RR community shrinking and aging; many are at universities, many have been closed

  -HFIR (Oak Ridge) and MURR are most significant isotope producers in U.S.

  -HFIR one of highest flux reactors in the world, sole producer of certain isotopes

  -MIT, UC-Davis, and Oregon State produce small quantities of research isotopes

  -ATR: A high-flux reactor used primarily for material testing, and currently producing Co-60, and has other isotope production capabilities.

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# IAEA Activities

## Status of Research Reactors and RI Production

- Small number of aging RRs supporting commercial radioisotope (Mo-99 from HEU targets) production:
  -NRU (Canada)
  -BR-2 (Belgium)
  -HFR Petten (Netherlands)
  -SAFARI (South Africa)
- LEU Mo-99 Producers: Argentina (since 2002); Australia/OPAL coming on line.
- No Mo-99 production in U.S. (MURR investigating, assessing – from LEU targets)
- Russian RRs (RIAR Dmitrovgrad) produce specialty isotopes, Russian nuclear research institutes and RRs re-organizing.
- Other international RRs are producing small quantities of various isotopes for local medical, industrial use
- Many international RRs are underutilized, some capable of producing significant quantities of isotopes (Chile, China, Egypt, Peru, Romania,)
- IAEA working to form Research Reactor Coalitions to increase availability of isotopes and improve reliability of supply

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# IAEA Activities

## Design Features for Isotope Production Reactors

- Dedicated, single-purpose facility for isotope production
- High reliability for uninterrupted operation at stable power with minimal outages for refueling and maintenance
- Low-Enriched Uranium (LEU) fuel and targets
- Long fuel cycle (e.g. lengthy period between refueling)
- Maximum number of irradiation positions in core, automated loading/unloading
- Excess reactivity available during entire fuel cycle
- Control system ability to manage reactivity effects (esp. during loading and discharge) and to adjust to flux perturbations and power peaks
- Substantial cooling and heat removal capabilities.
- Adequate shielding for target handling and storage
- Ancillary facilities including transfer channels to hot cells and glove-boxes for processing, shielded handling flasks, lifting devices, etc.
- Optimized physical security
- Minimization of waste generation, environmental releases, and personnel doses

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# IAEA Activities

## IAEA Mandate and Activities

- Functional mechanisms:

  -development of guidelines (TECDOC, TRS, other publications, Safety guides and standards)

  -fostering technology development and adaptation (CRPs)

  -technology transfer and capacity building (CRPs, TC projects)

  -information dissemination (meetings, publications)

  -promote cooperation, coalitions, networking, and partnerships

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# IAEA Activities

## IAEA Organizational Responsibilities

- NEFW - RR utilization and fuel, LEU targets
- NAPC - RR, cyclotron, and accelerator utilization and radioisotope production technology; nuclear data
- NAHU - nuclear medicine, clinical use of radiopharmaceuticals
- NSNI - research reactor safety; NSRW – radiation/waste safety; NSNS – physical protection
- TC - technical cooperation projects related to activities above

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# IAEA Activities

## Past/Recent Work and Publications

- Fission Molybdenum for Medical Use IAEA-TECDOC-515 (1989)
- Alternate Technologies for Tc-99m Generators IAEA-TECDOC-852 (1995)
- Management of waste from Mo-99 Production IAEA-TECDOC-1051 (1998)
- Production Technologies for Mo-99 and Tc-99m IAEA-TECDOC-1065 (1999)
- Charged Particle Cross-section Database for Medical Radioisotope Production: Diagnostic Radioisotopes and Monitor Reactions (CRP), IAEA-TECDOC-1211
- Manual for reactor produced radioisotopes, IAEA-TECDOC-1340 (2003)
- Consultants Report on Small-Scale Fission Molybdenum Production from Low Enriched Uranium, IAEA, July 2003
- Utilization Related Design Features of Research Reactors: A Compendium, IAEA TRS-455 (2007)
- Radiopharmaceuticals: Production and Availability, IAEA Nuclear Technology Review 2007 (Annex, p 60-71)

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# IAEA Activities

## On-Going Projects

- Coordinated Research Project (CRP) on Nuclear Data for the Production of Therapeutic Radionuclides (2003-2007)
- CRP on generator technologies for therapeutic radionuclides (2004-2008)
- CRP on Developing Techniques for Small-Scale Indigenous Production of Mo-99 Using LEU or Neutron Activation (T.1.20.18): on-going 2005-2009 (to be extended)
- CRP on Validation of Tracers and Software for Inter-well Investigations (2004-2008)
- CRP on Evaluation and Validation of Radioisotopes Generators-based Radiotracer for Industrial Applications (2007-2010)
- CRP on Therapeutic products based on Lu-177 for therapy (2006-2010)
- Consultancy (2007), Status Report (2008) and CRP on Aqueous Homogenous Reactors (AHR) for Radioisotope Production (2008-2011)

# IAEA Activities

## CRP on Mo-99 from LEU/Neutron Activation

- Initiated based on requests from IAEA Member States
- Dual Objectives:

  -support HEU minimization

  -foster capacity building for local/regional self-sufficiency and access to nuclear medicine, sustainable development
- Assist member states with adoption of LEU Cintichem (foil targets) or neutron activation (gel moly) technology.
- Further demonstrate efficacy of LEU production of Mo99
- NOT aimed at existing large-scale producers (they are participating/contributing)
- www.iaea.org/OurWork/ST/NE/NEFW/nfcms_researchreactors_Mo99.html

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# IAEA Activities

## CRP on Mo-99 from LEU/Neutron Activation

- November 2004 - Consultants Meeting and Report, Vienna
- February 2005 - CRP approved
- May 2005 - Workshop for Potential Mo-99 Producers, Buenos Aires, Argentina
- December 2005 - 1st Research Coordination Meeting (RCM), Vienna
- March 2006 – Workshop on Foil Targets, Serpong, Indonesia
- November 2006, October 2007 - Sessions at RERTR (Cape Town, Prague)
- November 2006 - Workshop on Operational Aspects of Mo-99 Production, Vienna
- April 2007 - 2nd RCM, Bucharest, Romania
- October 2008 - 3rd RCM,MURR, Columbia, Missouri

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# IAEA Activities

## CRP on Mo-99 from LEU/Neutron Activation

- Contract Holders:

  -Chile/CCHEN - LEU foil targets fission moly
  -Egypt/EAEA – fission moly and gel generators
  -Kazakhstan/INP - neutron activation/gel moly
  -Libya/DRETC - LEU foil targets fission moly
  -Pakistan/PINSTECH - LEU foil targets fission moly
  -Romania/IFIN-HH Magurele - neutron activation/gel moly
  -Romania/INR Pitesti - LEU foil targets fission moly

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# IAEA Activities

## CRP on Mo-99 from LEU/Neutron Activation

- Agreement Holders:

  -Argentina/CNEA
  -India/BARC-BRIT
  -Indonesia/BATAN
  -Korea/KAERI
  -Poland/POLATOM
  -US/ANL
  -US/MURR

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# IAEA Activities

## Summary

### Enhancing Isotope Availability, Reliability with Reduced Cost

- Addressing reliability and availability issues of ‘all *capable*’ reactors - safety/quality systems
- Assistance with development of strategic and business planning
- Strengthening of networking among major producers and reactors
- Fostering Research Reactor coalitions
- Encouraging additional producers located nearby usable reactors
- Enhancing back-up (*buffer*) production capacity of existing producers to the maximum extent possible
- Need for international/regional cooperation – *going beyond corporate competition*
- ***The IAEA role can be used to good advantage***

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# IAEA Activities

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- U.S.Department of Energy/NNSA/GTRI
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IAEA Points of Contact:

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